Chapter 25

Evidence for Climate Change From Desert Basin Palaeolakes

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Introduction

Lakes have long been recognized as being rich storehouses of environmental information. A lake basin collects water, but also sediment, much of which has been weathered and transported via fluvial processes from the near and far reaches of its drainage basin. The amount of water held in a lake is recorded on the landscape in coastal erosional and depositional landforms created at the water’s edge. The sediments deposited on the bottom of the lake can be clastic, geochemical, or biogenic, and include materials derived within the standing water body itself, such as through coastal erosion, chemical precipitation, or biogenic concentration, as well as those delivered to the lake from the surrounding drainage basin. In most cases only a small percentage of a lake’s sediment load is delivered from outside of the drainage basin as aeolian fallout. Because, under natural conditions, climate is the main determinant of the amount of water in a lake and because it influences some important characteristics of the lacustrine sediments and biota, changing climatic conditions are represented in the suites of abandoned shorelines and accumulations of sediments left by the lake over time (Fig. 25.1). This archival property makes the geomorphic and sedimentologic evidence of present and past lakes valuable as environmental and palaeoenvironmental indicators. Such evidence from late Quaternary palaeolakes, in fact, ranks among the most complete and accessible sources of palaeoclimatic proxy data currently available for the late Pleistocene and Holocene.

Earth scientists have conducted comprehensive studies of the geomorphic and sediment evidence of late Pleistocene and Holocene palaeolakes, and have made palaeoclimatic interpretations from them, since the late 19th century (Russell 1885, Gilbert 1890). Limited by poor age control, and to some extent by interest in other topics when the Davisian cycle of erosion paradigm was popular (Davis 1899), the number of palaeolake studies waned during the first half of the 20th century. About mid-century, palaeolake research began a slow but steady growth under the process geomorphology paradigm and as numerical dating techniques became established and increasingly refined. Eventually the growth in palaeolake research began to accelerate, along with interest in earth-system science, starting about 1980. Since approximately the mid-1990s, the number of palaeolake researchers and publications has grown dramatically reflecting...
increasing social and scientific concern with human impacts on the environment and global climate change.

Today, palaeolake investigations contribute to climate studies in many ways. Researchers work on accurately reconstructing details of the timing and extent of palaeolake-level fluctuations (e.g. Fornari et al. 2001, Godsey et al. 2005), estimating the local and regional values of climatic variables and circulation attributes that could have led to those fluctuations (e.g. Benson 1993, Bookhagen et al. 2001, Stone 2006, Dühnforth et al. 2006), searching for spatial and temporal similarities and differences in the behavior of multiple palaeolakes (e.g. Benson et al. 1995, Krider 1998, Mensing 2001, Zhang et al. 2004, Balch et al. 2005), and comparing the palaeoclimatic signal determined from palaeolakes with climatic signals derived from other sources (e.g. Benson et al. 1998, Broecker et al. 1998, Lin et al. 1998, Stager et al. 2002, Balch et al. 2005). These efforts provide information on the amount and rate of natural climate variability experienced during the late Quaternary, and therefore on what might be possible in the future. They supply a record of past climatic conditions that emerging models of global climate change should be able to successfully hindcast. Furthermore, comparing fluctuations in various palaeolakes around the globe with oscillations present in such data sources as the marine oxygen-isotope record, the Greenland ice cores, and the earth’s orbital parameters helps scientists understand the mechanisms, sensitivities, and teleconnections of the natural climate system. Clearly, reconstructing the timing and extent of palaeolake fluctuations is the scientific foundation that makes these applications possible.

Desert Basin Palaeolakes

Lakes form wherever there is an adequate basin of containment and enough surplus water to accumulate in it. Topographic depressions that function as lake basins may be derived from a wide variety of sources. They originate through tectonic, volcanic, fluvial, aeolian, mass wasting, glacial, meteoritic, or other processes (Hutchinson 1957). Most lakes in humid climates receive so much inflow that the level of the standing water body permanently attains, and continually spills out over, the lowest point along the boundary of the containment basin. This low point is called the sill or threshold, and in humid regions the overflowing stream is typically part of an integrated, throughflowing, fluvial drainage system. Such open-basin, or externally drained, lakes have the elevation of their water level controlled by the elevation of the threshold. An increase of flow into an open-basin lake is handled by an increase in discharge out of the lake. Although the cross-sectional depth of the stream flowing out over the threshold will vary to some extent with discharge, much of the variation in volume of water is accounted for instead by the other two fluvial discharge variables, cross-sectional width and velocity of flow. As a result, the water level of open-basin lakes tends to be maintained very near the elevation of the threshold. Although this can lead to strongly developed coastal landforms within that narrow vertical zone, threshold control largely prohibits changes in the amount of water delivered to the lake from being sensitively recorded in distinct, multiple shorelines. A detailed record of changing conditions of effective moisture is thus lost. Alternatively, successively lower shorelines sometimes form in open lake basins as a result of fluvial erosion of the threshold and irrespective of vacillations in the regional effective moisture.

In many arid regions, topographic basins are commonly not connected with each other by throughflowing surface drainage, and this is primarily due to climatic factors (Langbein 1961). As in other climatic regions, topographic basins that may pond water can be formed by a variety of processes. In desert environments, however, once a large basin exists it is unlikely that sufficient surface water will be generated to completely fill the containment basin, spill over, and contribute to an integrated surface drainage system that reaches ultimate base level. Some desert basins contain perennial lakes while many others currently support only ephemeral or intermittent lakes (playas or playa lakes) (Mifflin and Wheat 1979, Smith and Street-Perrott 1983, Williams and Bedinger 1984). Perennial lakes in desert basins tend to be closed-basin, or subthreshold, lakes rather than open-basin lakes. As a result, they may exist for long periods of time because they are not destroying their own basin closure by fluvial erosion at the threshold. More importantly, by not being threshold controlled, the lakes are free to fluctuate in level in response to changes in effective moisture leaving telltale coastal landforms at a variety of water stillstand levels. The largest desert lakes in existence